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Inheritance of Fiber Strength in an Interspecific Cross of Cotton.

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ABSTRACT

Inheritance of fiber strength, was studied in the F_1 and first and second segregating generations of an interspecific cross between DPL 15 (Gossypium hirsutum) and Sea Island (Gossypium barbadense). Fiber strength was measured with the Pressley Fiber Strength Tester, utilizing Pressley index and 0.125 inch strength index. In measuring Pressley index the clamps of the tester were set as close together as possible while for determination of 0.125 inch strength index the clamps were set one-eighth inch apart by use of a spacer of that width.

The small variation among plants within the parental populations was primarily due to environment. The F_1 was less subject to environmental variation than the parents. Fiber strength behaved as a quantitative character. Partial dominance of low Pressley index (weak fiber) occurred; however, fiber strength at 0.125 inch strength index showed absence of dominance.

Attempts were made to estimate the number of genes segregating for fiber strength. Parental means differed by 2.81 units of Pressley index and 2.27 units of 0.125 inch strength index. Parents, F_1, F_2 and F_3 populations were used in the estimates. Three methods of estimation of the minimum number of genes were used. All estimates indicated that fiber strength was conditioned by a relatively small number of genes. There appeared to be more genes segregating for 0.125 inch strength index than for Pressley index.

The reliability of estimates of heritability varied. F_3 results were found most reliable in the estimation of heritability and indicated that 50 to 60 per cent of the high strength F_2 plants produced high

strength F_3 lines. Thus selection for fiber strength on the individual plant basis would be highly effective and desirable.

There was no relationship between fiber strength and seed index, lint density index, lint index, lint per cent, and immaturity or shape factor in either the F_2 or F_3 population.

In the F_2 population, Pressley index showed a highly significant, low negative relationship with wall thickness and weight fineness. The 0.125 inch strength index showed a significant negative association with wall thickness and perimeter, and a highly significant but low, correlation with weight fineness. The correlations between fiber strength and these fiber fineness components were interpreted as being physical in nature as similar values were obtained among plants of the parental populations.

In F_2, the correlation coefficient between the two measures of fiber strength was 0.74 and among means of F_3 lines the r value was 0.62. Both r values are highly significant, indicating relatively close association between Pressley strength index. However, there were several exceptions to this association among the 80 F_3 lines. Some were high in Pressley index but only average to low in 0.125 strength index, while other lines were high in 0.125 inch strength index but intermediate to low in Pressley index. Neither measure of strength could have been used as a completely reliable estimate of the other.

INTRODUCTION

During the past decade the textile industry has experienced increasing competition from synthetic fibers. In some cases, the synthetic yarns have been found to be superior to cotton yarns, but usually in only a very few characteristics. The competition from man made fibers has been of two distinct types: (1) The competition from rayon and acetate fibers has been primarily due to the price differential, the man-made cellulose fibers being cheaper than cotton, and (2) the special competition from nylon, dacron, orlon and others, which, though considerably more expensive than cotton, possess special qualities such as extra high strength. Improvement in the strength of cotton fiber would tend to render cotton more competitive with the latter group of synthetic fibers.

Although the strength of cotton may be slightly modified by cultural changes, i.e. changes in environment, the amount of change needed cannot be accomplished except through breeding for superior strength. The cotton breeder is concerned with both quantity and quality of fiber. Yield is highly influenced by environmental conditions whereas fiber strength is primarily genetic.

Generally the textile industry feels that the Southern upland cottons are somewhat lacking in fiber strength. The concensus is that Southern upland cottons could be improved if the fiber strength were increased. However, diverse opinions are offered as to the amount of desired additional strength. This depends upon the manufacturer and the end product which he produces. Fiber strength and yarn strength are closely associated, and there is general agreement that the best method of improving yarn strength is by the improvement of fiber strength, as approximately 88 per cent of yarn strength can be accounted for by fiber strength.

Most of the cotton of the southeastern United States is generally weak (low fiber strength), as compared to the cottons of the irrigated southwest. However, at the present time, cotton price is determined by grade and staple, with little, if any, premium being paid for higher strength. Thus far, breeders have failed to establish high strength varieties which are adapted to the southeast.

There are three known sources of high fiber strength. These are:

(1) Gossypium hirsutum variety punctatum, or Hopi cotton from the Hopi Indians of Arizona,

(2) Gossypium barbadense, The Sea Island and American-Egyptian varieties especially, and

(3) the tri-species hybrids involving the cultivated Asian species, G. arboreum, the American wild species G. thurberi, and upland cotton (G. hirsutum). In this complex situation, the first two species are crossed, the F_1 is treated with colchicine in order to double the chromosome number, and then this doubled F_1 is crossed with upland. Repeated backrosses to the upland cottons have failed to transfer genes for strength without also transfering deleterious genes for other characters.

In view of these facts, a hybridization program has been initiated at the Louisiana Agricultural Experiment Station in an effort to transfer the genes for superior fiber strength of Sea Island into upland cotton.

A thorough understanding of the nature of inheritance of fiber strength in this interspecific hybrid is necessary in the planning of an efficient, productive breeding program.

The available literature contains little information pertaining to the nature of inheritance of fiber strength in crosses involving the species G. hirsutum and G. barbadense. This lack of data is understandable, in that prior to the invention of the "Pressley Fiber Strength Tester", there was no rapid, accurate means for determining fiber strength for individual plants. This tester was designed by Dr. E. H. Pressley (14) of the Arizona Agricultural Experiment Station and became generally available around 1940. However, the majority of the work done with segregating populations of crosses between G. barbadense and G. hirsutum was done during the period around 1920, or earlier. Thus, at the time when the studies were conducted, the usual determinations of fiber strength were made on the basis of hand breaks, plants being classified simply as either strong or weak.

This investigation was undertaken to study the inheritance of fiber strength in a cross between varieties of G. hirsutum and G. barbadense. Specific objectives were:

(1) To determine whether fiber strength is inherited as a quantitative or qualitative character.

(2) To determine the presence or absence of dominance.

(3) To determine the nature of gene action, whether arithmetic or geometric.

(4) To estimate the minimum number of genes by which the parents differed.

(5) To determine the degree of heritability for strength of fiber.

(6) To determine, by correlations, whether or not relationships exist between fiber strength and other characters, and the nature of these relationships.

(7) To determine the relationship between fiber strength measurements with the "Pressley Fiber Strength Tester" made at the 0 inch and 0.125 inch gauge.

REVIEW OF LITERATURE

There have been very few investigations of inheritance of fiber strength. In practically all early cases where segregating populations were used, conclusions were drawn on the basis of a relatively small population, and the means of determining fiber strength were very crude.

The available literature shows that Mell[12] studied hybrids of upland and Sea Island in 1894. However, no record was made concerning fiber strength.

Balls[1] stated in 1919 that no methods for determining strength of small samples of fiber were available. However, it was possible to determine breaking-strain, but an enormous amount of labor was involved in order to give a reasonable probable error. In fact, Balls regarded the method as "hopeless" on large samples. The method of determining fiber strength, that of the thumb and forefinger of an expert, were relied upon almost entirely.

Fiber strength measurements of small samples had progressed very little twenty years later when Harland[7] published his book on cotton genetics. In fact, up until that time, all fiber strength determinations on individual plants were made by hand as in Balls' time.

McLendon[11] reported "weak" fiber dominant to "strong" and Sea Island quality dominant to upland quality. The lint of the Sea Island was reported to be the weaker of the two types. His conclusions concerning inheritance of fiber strength were based on studies involving the following crosses: (1) Sea Island X Cooks Big Boll, (2) Sistrunk X Sea Island, (3) Pride of Georgia X Sea Island, and the reciprocal, (4) Hasting's Big Boll X Sea Island, and the reciprocal, and (5) Toole

X Sea Island and the reciprocal.

Kearney[9] worked with the F_2 and F_3 generations of a cross between Holden (G. hirsutum) and Pima (G. barbadense) to obtain statistical data as to the nature and behavior of variants to be expected in cotton fields of either species when exposed to natural cross-fertilization of the two species. This information was to be utilized in guiding the work of roguing seed increase fields. Due to this fact, and to the lack of a means of measuring some of the fiber properties, Kearney was primarily concerned with botanical characters of the plant. However, he made some observations concerning fertility and the level of productivity of the segregating populations. Kearney observed that the F_1 of the Holden X Pima cross was extremely fertile. The F_2 showed "absolute sterility" on 7 per cent of the 215 F_2 plants. In addition to the completely "sterile" plants, a low degree of fertility was not infrequent. Many F_2 plants produced seed which had low viability, and there was a loss of a considerable number of seedlings among the F_3 progenies. In approximately 25 per cent of the hills, no plant developed beyond the seedling stage even though each hill contained three to four seeds.

Ware[19] reached the same conclusions as Kearney concerning fertility levels of the segregating generations. Very little reliable data were obtained on F_3 plants of three crosses of G. hirsutum and G. barbadense. No report was made of any study of inheritance of fiber strength.

Moore[13] made measurements of breaking load, or strength of single fibers, from six different regions of individual seed from five varieties of upland cotton. He found, in general, the strongest fibers to be on the micropylar end of the seed with a general decrease in fiber strength approaching the chalazal end. Fiber strength was measured on a testing machine of the balance type. The breaking load was added to the beam at the rate of one-tenth gram per second and was recorded to the nearest one-one hundredth (0.01) gram. The breaking load was applied to the three-eighth (3/8) inch midportion of the fiber. Significant differences in fiber weight, strength and density of fiber population were found from the micropylar to the chalazal end of the seed. The thicker, stronger fibers occurred in the micropylar end, and the thin-walled fibers and denser fiber population were found in the chalazal region.

One of the earliest reported studies of fiber strength in segregating populations, in which a rapid accurate means of measuring fiber strength was used, was that of Ware and Harrell[20]. They grew F_1, F_2, F_3, and two generations of backcrosses to each parent, from a cross of Florida Green Seed and Rowden, both upland varieties. The parents differed by approximately one Pressley index unit, the Florida Green Seed variety being the stronger parent. Results were somewhat varied, but on the average, indicated that inheritance of strength of fiber was quantitative in nature. The F_1 was intermediate. The mean of the 87 F_2 plants was slightly above the average of parental means. The F_3 progenies were reported to be more variable than either parent, but that these progenies tended to maintain the level of the F_2 plants from which the lines originated.

Hancock[6] in an experiment to determine the differences among varieties in the expression of strength and to consider the influence of environment on this character, grew ten varieties of upland cotton in three locations having different soil types. Strength was measured with the Pressley fiber strength tester. He found large differences between individual plants within a variety, as well as differences between varieties, and indicated that strength seemed sensitive to small soil differences in some tests.

Gonzalez[4] investigated the correlation of quantitative characters in the first segregating generation of a cross between two upland varieties which differed little in strength. Parental varieties were Delfos 9169 and (A x B) 293, which was a selection from an F_4 of a Wilds X Half and Half cross. In this study, Gonzalez found wide variation within each parent, and that the F_2 showed a normal curve characteristic of quantitative characters. From this data, he concluded that the mode of inheritance was quantitative in nature and conditioned by multiple factors.

Isaac[8] in a study involving the F_2 of a cross between Stoneville and Delta Smooth Leaf, having similar Pressley indexes, found that the F_2 population exhibited a unimodal curve which was slightly skewed toward the weak side. He concluded that his results were similar to the frequency distribution obtained with most quantitative characters showing inheritance characteristic of multiple factors.

Stafford[16] studied the inheritance of fiber strength and perimeter in a cross of Wilds and Half and Half. He found that mean Pressley index of the F_1 and F_2 was slightly below the arithmetic average of the parents, and concluded that this indicated partial dominance of weak fibers. No conclusions were drawn concerning the nature of gene action, however, fiber strength appeared to be conditioned by a small number of genes, probably three to four pairs. F_3 results were found to be more reliable than the heritability formula used with the F_2 population to estimate heritability. Heritability estimates based on F_3 data indicated it would be advisable for a breeder to select rigidly in a large population in order to insure selection of an adequate number of superior plants.

Self and Henderson[15], in an investigation of inheritance of fiber strength in a cross of AHA 50 and Half and Half, found the F_1 mean of 8.2 to be slightly lower than the parental average, but essentially intermediate. Parental means were 9.8 and 7.1 respectively. The F_2 population of 806 plants had a continuous range from 6.6 to 9.9 Pressley index. F_3 lines were planted in a randomized block design with three replications. Fiber strength obviously was inherited as a quantitative character. The Castle-Wright formula, for estimation of minimum number of genes, gave an estimate of 5 pairs. The F_3 lines originated from 66 F_2 plants representing the complete F_2 range. However, particular effort was made to include a comparatively large number of plants within each of the parental ranges. Therefore the F_3 lines were not derived from randomly selected plants.

Progeny tests of the F_3 indicated that there was a probable recovery of one or more plants representative of each parental genotype. In view of the frequency of recovery of parental phenotypes, the authors felt that a more probable estimate of gene number would be four.

The estimates of heritability, based on the correlation of F_2 plant phenotype with F_3 line mean, and regression of F_3 line mean on F_2 plant, gave coefficients of 0.76 and 0.53, respectively.

Lewis[10], in a trispecies hybrid, found a highly significant correlation of 0.562 between F_2 and F_3 for fiber strength.

Correlations of Characters

Due to the fact that there were no rapid, accurate methods of testing some of the major components of fiber quality, on an individual plant basis, until after 1940, there is little available information concerning interrelationships between these components prior to this time.

Stroman[17], quoting Gulate and Almad, reported significant correlation coefficients of 0.72, -0.46, and -0.71 between mean fiber strength and the following degrees of fiber maturity: mature hairs, half mature hairs, and immature hairs.

Stroman[17], reported that in his work with strains of Acala, fiber strength was not strongly correlated with any characters used, although there was a significant, small, negative correlation between strength and lint per cent in 1944 and 1946. Strength was positively correlated with fiber diameter in 1944 and showed a negative correlation in 1945.

Moore[13] reported correlation coefficients between the average strength of fiber and the following characters in 5 upland varieties: density of fiber population, average fiber weight, average fiber diameter, and per cent thin walled fibers. Correlation coefficients between strength and density of fiber population ranged from a low of -0.427 in Rowden to -0.715 in Coker-Cleveland 884-4. All coefficients of fiber strength with fiber density were highly significant. Average fiber strength and average fiber weight showed highly significant positive correlations for all varieties. The coefficients ranged from 0.383 to 0.797. The per cent of thin walled fibers and average fiber strength were negatively correlated and highly significant. The range of magnitude of these coefficients was from -0.583 to -0.775 in the Mexican 128 and Acala 4067 varieties. Average fiber diameter and fiber strength showed a significant negative relationship in only one variety, Farm Relief No. 1.

Hancock[6] from results of his study of fiber length, fineness, and strength, as related to environment and heredity, concluded that fiber strength was independent of length and fineness under controlled conditions, strength and length were negatively associated.

Gonzalez[4] found no association between fiber strength and lint per cent, seed index or length.

Isaac[8] reported no correlations between strength and lint per cent, seed index, lint index, or length.

Green[5] in a study of 285 strains of upland cotton, found no highly significant relationships between strength and length, fineness, seed index or lint index. However, he found a significant correlation between strength and lint per cent. This value, -0.242, was considered to be so low that it would be of little importance in a breeding program.

Stafford[16], in a cross of Wilds and Half and Half, found no association between fiber strength and the following characters: lint index, seed index, lint per cent, lint density index, perimeter, wall thickness, weight fineness and immaturity (shape factor).

Barre[2] discussed the relationship between fiber strength and fineness and stated that there was no available evidence to show that fiber fineness has any marked effect on fiber strength as determined by the bundle method. In 1947, when Barre made this report, there was no means of dissociating components of fiber fineness. He felt that the association of fiber strength and fineness in some varieties could probably be accounted for by spiral structure, size of crystallites, and other physical properties. Barre pointed out that when cotton was grown under less than adequate soil moisture conditions, the fibers would be shorter than the varietal average. If the dry conditions persisted throughout secondary wall formation, the short fibers would have better than average structure and strength and increased fineness.

Lewis[10] in a trispecies hybrid reported that, in the F_3, lint strength was positively correlated with fineness, length and seed index. These values were small and only length showed a highly significant correlation. Lint strength was negatively associated with perimeter. This value, (-0.359) was highly significant.

MATERIALS AND METHODS

The materials used in this investigation consisted of the parents, F_1, F_2, and F_3 generations of a cross between upland (Gossypium hirsutum) and Sea Island (G. barbadense) types of cotton. The upland parent used in this cross was Delta Pine 15, the most widely grown commerical variety in Louisiana, and the Sea Island parent used was from the Stoneville, Mississippi collection and designated as Sea Island (SA339).

The original cross was made in 1954, following standard crossing procedures. All hybrid seed from which the segregating populations were grown came from one plant of each parent species. The hybrid seeds were harvested in the fall of 1954. A portion of these hybrid seeds was sent to Iguala, Mexico, where seven F_1 plants were grown during the winter of 1954. The parental populations in the study were derived from selfed progeny of the same plant of each species used in the cross. Each parent variety had been inbred by controlled selfing for several generations in order to insure its homozygosity.

The F_2 population was derived from selfed seed of those plants grown in Iguala. By growing part of the F_1 population in Mexico during the winter, one year was saved, thus F_2 seed was available for planting in the spring of 1955.

In mid May 1955, selfed seed of the parent plants involved in the cross, F_1 seed, and F_2 seed from the F_1 plants grown in Mexico were planted on the Perkins Road Agronomy Farm on Olivier silt loam soil. The soil was fumigated with one gallon per acre of Nemagon three weeks prior to planting, and six hundred pounds per acre of 8-8-8 fertilizer was applied. Three to four seeds were planted per hill, with hills 20 inches apart on 42 inch rows. After the stand was established, seedlings were thinned to one plant per hill. Insecticides were applied when necessary in order to control injurious insects.

The parent plants and the F_2 population were selfed. Considerable difficulty was experienced in securing sufficient selfed seed on the F_2 plants. The usual selfing procedure followed at the Louisiana Agricultural Experiment Station, i.e. bagging with one-half pound Kraft paper bags, proved unsatisfactory for the F_2 plant population. Sterility and several types of flower malformation, primarily the latter, seemed to cause this difficulty. The apparent sterility encountered may have been due to either genetic or physiological condition. Selfed seed on some of the F_2 plants were finally secured by bagging flowers, and on the morning of anthesis, shaking the bag vigorously. Even when this self-pollinating technique was used, only 102 F_2 plants produced as many as 40 selfed seed.

Just prior to harvest, each plant in the population was tagged for identification. Harvesting was initiated in mid-October and extended over a period of six weeks. The final picking was made after the first killing frost. Seed cotton from each plant was kept in a separate paper bag which bore the proper identification number of that particular plant.

The seed cotton from each plant was ginned separately on a laboratory roller gin.

The F_3 generation consisted of 25 hill plots, each plot arising from the selfed seed of an individual F_2 plant. The hills were spaced 24 inches apart on 42 inch rows.

Prior to planting the F_3 population, the area was fertilized with 800 pounds dolomitic limestone and 600 pounds of 6-8-8 fertilizer. The area was fumigated for nematode control with 4 gallons ethylene dibromide W-85 per acre.

The F_3 progenies (lines) and 7 plots of each parent were planted on May 7, 1956. Hills were thinned to 1 plant per hill, or if hills were missing, an attempt was made to leave 25 plants per progeny. Insecticides were applied to the area when necessary to control injurious insects. The parent progenies, with the exception of three plots of Sea Island which arose from open pollinated seed of plants grown in the greenhouse, were from selfed seed, and were spaced in pairs, at 14 plot intervals, throughout the entire area in order to give an estimate of environmental variation.

Each plant in the entire study was tagged prior to harvest with proper identification. Plants were harvested individually as in the previous year. Harvesting extended over a period of six weeks, beginning the first week in October. The majority of the seed cotton was obtained during the first two weeks of October.

Seed cotton from the individual plants was ginned in the same manner as in the previous year.

Each plant of the F_1, and F_2, and parent plants grown along with these generations, were sampled for fiber strength determinations in the following manner:

(1) Grasp the lint sample with both hands and pull apart.

(2) Place both portions of the sample in one hand so that broken ends are together.

(3) Smooth "face" of sample by pulling out matted tufts of fibers.

(4) Pull, with thumb and forefinger of free hand, a random sample (bundle) of fibers from entire "face" of lint sample. The above procedure was then duplicated to secure a second sample (bundle).

(5) Comb the samples (bundles) to orient the fibers in a parallel manner and to remove extraneous material.

(6) Place samples (bundles) of fiber in a coin envelope bearing proper plant identification and return lint sample to original bag.

In 1956, the lint samples from each parent and F_3 plant were blended on a small laboratory fiber blender. The lint sample, as taken from the blender, was in the form of a ribbon of essentially parallel fibers. This ribbon was doubled and refoubled lengthwise, grasped at right angles to the longitudinal axis of the ribbon and pulled apart. Sampling procedure was the same as previously outlined except that step 5 was eliminated because of fiber orientation during blending.

Fiber strength determinations were made with the Pressley Fiber Strength Tester. This tester was designed by Dr. E. H. Pressley of the Arizona Agricultural Experiment Station (14). When first designed, strength determinations were made on the basis of the number of pounds of force required to break one milligram of cotton cut to the width (0.464 inches) of the clamps used for breaking the fiber. This value, the number of pounds required to break one milligram of cotton fibers cut to the standard length, became known as Pressley index. About 1953, due to research work on fiber strength testing equipment by physicists at the University of Tennessee, the "Pressley Fiber Strength Tester" was modified to the extent that a spacer of 0.125 inches was placed between the clamps.

This modification of the tester gave a strength value which showed a higher correlation with yarn strength than did the Pressley index or 0.0 inch break.

Fiber strength determinations were made in the following manner:

(1) Pull the small tuft of fibers from the end of one of the samples (bundles) which were stored in the coin envelope.

(2) Pull the tuft of fibers through the comb attached to the torsion vise used with the tester. The tuft is pulled through the comb to make a parallel ribbon of fibers and to remove short, broken fibers, trash and neps. Precautions are observed to comb all samples in the same manner in order to minimize bias.

(3) Place combed ribbon of fibers in open clamps held in torsion vise.

(4) Close clamps and tighten top screws of clamps until torsion vise starts twisting. Use of the torsion vise assures uniform tightness of the clamps.

(5) Place clamps in tester and release rolling weight, allowing it to roll down beam of tester until ribbon of fibers in clamps is broken.

(6) Record, to the nearest one hundredth (0.01) pound the beam reading, which fell between 13.50 and 19.00 pounds. Values which were below this range (below 13.50) are not accepted because of possible bias due to small sample size. Those which are above this range (above 19.00) are not accepted because of possible bias due to overshoot of weight (distance weight travels after ribbon of fibers breaks).

(7) Remove clamps from tester and cut the fiber extending from sides

of clamps flush with clamp edge, establishing the standard length of ribbon of fibers for strength determinations.

(8) Place clamps in torsion vise, loosen top screws and carefully remove broken ribbon of fibers.

(9) Place broken ribbon of fibers on weighing arm of milligram balance and weigh to nearest one-hundredth (0.01) milligram.

(10) Divide beam reading for the ribbon break by the weight of the ribbon in milligrams. The quotient is the strength value recorded for the bundle.

(11) Another strength determination is made as outlined in steps 1 through 10, utilizing the remaining bundle of fibers in the coin envelope. These two determinations are averaged to establish strength value of the plants if they were within specified tolerances. Tolerances were: 0.25 units Pressley index and 0.15 pounds per milligram for the 0.125 inch break. In cases where these tolerances are exceeded, an additional break is made from each bundle. These additional breaks are required to meet the above tolerances, both within and between bundles. In these cases, the four breaks are averaged to establish the strength value for the plant. In cases where the second breaks on each bundle do not meet the above requirements, a third set of breaks from each bundle is made. If the values within both bundles are within prescribed tolerances, an average of the six breaks is accepted as representative of the plant.

The rate of travel of the rolling weight was adjusted so that at least three seconds elapsed between the time of release of the weight and the time the weight reached the maximum limit of travel. This rate was found to be the minimum which could be used in order to provide free rolling of the weight and a minimum of overshoot.

Fiber strength determinations were made for individual plants of the parents, F_1 and F_2, using both the Pressley index and the 0.125 inch breaks, by the procedure previously outlined. Breaks were made on a check cotton at 10 plant intervals to provide a basis for converting results to standard conditions for evaluation. The check cotton was sampled in the same manner as the plants to avoid bias.

Fiber from the F_3 generations plants was sampled and tested as previously outlined. However, the entire F_3 population was tested using only the 0.125 inch break. Check samples were tested before the first plant, after each ten plants and after completion of all plants on each progeny. These checks were averaged, a conversion factor was calculated, and the average for each plant was multiplied by the conversion factor to establish plant strength value.

A one gram sample of lint was taken from each of the first ten plants of each of the 80 F_3 lines and the seven plots of each parent. These ten one gram samples per line were bulked and blended to give a ten gram lint sample per line or row. Pressley index was determined for each of these samples, using the average of a minimum of six breaks per line. This average value of Pressley index for the bulk sample was compared with the arithmetic mean of the 0.125 inch strength index of the same ten individual plants. A correlation coefficient was calculated between Pressley index determinations on the ten plant bulk line sample and the arithmetic mean of 0.125 inch strength index of the same ten plants.

Random plants from the entire population were retested for fiber strength in order to determine reliability of the determinations. There was a total of 160 random plants retested. Of these plants, 150 were within one unit standard deviation (0.20) of the original values, and ten were less than 2 units standard deviation. Thus, fiber strength determinations were essentially duplicated, indicating that the results were reliable.

The degree of variation between plants within populations was determined by use of the common statistics, range, standard deviation and coefficient of variation.

Dominance was studied by comparison of observed and expected means of the F_1 and F_2 populations. The frequency of parental genotypes (phenotypes) and distribution of plants in segregating populations were also compared with that expected when only straight additive and equal gene effect is assumed.

The nature of gene action was indicated by a comparison of actual, or observed, means of the F_1 and F_2 with their expected arithmetic and geometric means.

The following methods were used in estimation of the minimum number of genes by which the parents differed: (1) The Castle-Wright Formula (2) The Wright Formula, as proposed by Dr. Sewell Wright, Department of Zoology, University of Chicago, and used by Burton(3) in a study of the inheritance in pearl millet. (3) The frequency of recovery of parental genotypes as indicated by the mean of the F_3 line. Those lines having a mean closely approximating either parent were examined to determine, on the basis of a comparison of values for coefficient of variation and frequency distribution of the F_3 line and the parent, whether the F_3 line represented a genotypic recovery.

A comparison of the total number of F_2 plants phenotypically similar to each parent, and the number of these which, when carried as F_3 lines, proved to be genotypic parental recoveries, established the frequency of recovery of parental genotypes. A comparison of the frequency of recovery of parental genotypes with that expected from a given number of genes in Mendelian inheritance was used as a basis for estimating the number of genes by which the parents differed.

Heritability values from the F_2 population were determined by the following formulae:

$$(1) \quad HF_2 = \frac{s^2F_2 \;-\; s^2\,e}{s^2F_2}$$

Where:

$H\,F_2$ is estimate of heritability in the F_2

s^2F_2 is F_2 mean square

s^2e is $\dfrac{s^2P_1 \quad s^2P_2}{2}$

$$(2) \quad HF_2 \qquad \frac{s^2F_2 - \dfrac{s^2P_1 + 2s^2F_1 + s^2P_2}{4}}{s^2F_2}$$

Where:

$H\,F_2$ is heritability in F_2

s^2P_1 is mean square for one parent

s^2P_2 is mean square for other parent

s^2F_1 is mean square for F_1

s^2F_2 is mean square for F_2

Heritability studies with the F_3 generation were computed by the following procedures:

(1) The correlation coefficient for means of the F_3 lines with the values of F_2 plants from which the F_3 lines originated.

(2) The regression coefficient of F_3 line means on values for F_2 plants.

(3) Estimation of the degree of reliability which could be placed on superior F_2 plants to yield superior F_3 progenies.

This was accomplished by comparison of F_2 plant values with F_3 line means.

Simple correlation coefficients were calculated between the two measures of fiber strength and also between each measure of fiber strength and the following characters which were measured for the F_2 population: (1) seed index, (2) lint density index, (3) lint index, (4) lint per cent, (5) wall thickness, (6) perimeter, (7) weight fineness, (8) immaturity.

In the F_3 population, simple correlation coefficients were calculated between the line mean 0.125 inch strength index and all characters, with the exception of immaturity.

A bulk sample of each F_3 line made from one gram of lint from each of the first ten plants of the line was blended and tested for Pressley index. The Pressley index of the blended bulk sample was correlated with the mean 0.125 inch strength index of the ten plants used in the blended sample.

Individual plants of each plant of the parental population grown along with the F_3 population were tested for 0.125 inch strength index. These strength values, in each population, were correlated with wall thickness, perimeter, and weight fineness.

RESULTS AND DISCUSSION

In 1955, a population consisting of the parental varieties, DPL 15 and Sea Island (SA 339), and the first two generations of the hybrid, were grown.

These populations were tested, on an individual plant basis, for fiber strength. Two meansures of Fiber strength were utilized in the evaluation of the individual plants. One measure was made with the clamps of the Pressley Strength Tester set together without appreciable space between them and the other with the clamps separated by 0.125 inch. In this study, the first measure will be designated Pressley index, a term already in common usage, while the second, for convenience, will be designated 0.125 strength index.

The parental and the F_1 populations were grown on one row along the side of the F_2 population. The DPL 15 and F_1 populations consisted of 20 plants each, whereas the Sea Island parental population consisted of 25 plants.

The F_2 population of the cross of DPL 15 and Sea Island (SA 339), hereafter referred to as Sea Island, consisted of 406 plants. Only 373 plants were included in the genetic study because 18 plants did not produce any cotton at all, and an additional 15 plants produced insufficient cotton from which to prepare samples for breaking. The failure of 8% of the plants to produce sufficient fiber for strength determination was due in most cases to sterility, a common condition encountered in F_2 and later segregating generations of hybrids between G. hirsutum and G. barbadense. The F_1 population was fully fertile, all plants producing an adequate amount of fiber for testing, and no evidence of any type of sterility.

The parents, F_1 and F_2 plants were harvested over a period of six weeks.

Three harvests were necessary in order to secure samples from as many plants as possible. At the time of the first picking, approximately 20 20 per cent of the plants had enough open bolls to constitute an adequate sample. All plants of the DPL 15 parent were sampled at this time.

An additional 40 per cent of the plants matured enough bolls to constitute an adequate sample in the second harvesting period. At this time, the F_1 population was sampled, whereas the Sea Island parent population required a third harvesting in order to secure adequate samples for each plant.

The remaining 40 per cent of the F_2 population required a third picking in order to secure adequate seed cotton for testing purposes. This final harvest was made after the first killing frost and may provide the basis for a small bias in fiber strength determinations for those late maturing plants.

The F_3 plant population arose from selfed seed of individual F_2 plants. Plants were taken at random, as far as any particular character was concerned, the only requirement being that the F_2 plant set a minimum of 40 selfed seed. There were originally 102 lines, but only 80 lines produced 10 or more mature plants from which adequate samples could be taken for measurements of fiber strength. The failure of many lines to produce a minimum of 10 plants with enough cotton for testing was due to poor seedling stand (germination and emergence), which may or may not have been partially of a genetic nature, and partial sterility of plants. As a whole, approximately the same amount of unproductivity was observed in both the F_2 and F_3 generations.

Grown along with, and equidistant between F_3 progenies, were paired progeny rows of the parental varieties. The parental varieties were spaced in this manner in an attempt to secure a more reliable estimate of environmental variation for the area. The parental populations consisted of 167 and 150 plants of DPL 15 and Sea Island, respectively.

Two dates of harvest were used for the F_3 and parents. The time lapse between the completion of the first picking and the initiation of the final harvest was about three weeks. The majority of the cotton harvested from the F_3 progenies was included in the first picking. Both parental varieties were harvested at the same time in the first picking; thus, those plants requiring additional time to mature enough seed cotton to constitute a sample were either very late in maturity, yielded very little, or had a combination of these two characters.

Inheritance of Fiber Strength as Measured by Pressley Index

Pressley index was determined for each plant of the parent, F_1 and F_2 populations, and also for a blended bulk sample from the first ten plants of each F_3 line. The frequency distribution, mean, standard deviation, coefficient of variation and number of plants in each of the parental, F_1 and F_2 populations are shown in Table I.

The DPL 15 parent population consisted of 20 plants. The mean Pressley index was 7.08, with a range from 6.05 to 7.56, a variation of 1.51 units. The coefficient of variation was 4.2%. One plant of the DPL 15 parent may have been diseased, as the Pressley index of this plant was at least 0.51 units lower than the remainder of the DPL 15 parent. This plant was not discarded because a comparison of other characters did not show the plant to be off type.

Twenty-four plants of the Sea Island parent population were tested for Pressley index. The Sea Island population had a mean Pressley index of 9.89, and a range from 9.41 to 10.40 units. The coefficient of variation was 2.8%

TABLE I

Frequency distribution of fiber strength (Pressley index) for F_1, F_2, and parent populations of a cross between DPL 15 and Sea Island.

Population	Number of plants in following strength classes													Total	Mean	Standard Deviation	C.V. %
	5.8	6.2	6.6	7.0	7.4	7.8	8.2	8.6	9.0	9.4	9.8	10.2	10.6				
DPL 15		1	1	12	6									20	7.08	0.30	4.24
Sea Island										5	9	10		24	9.89	0.28	2.78
F_1					4	14	2							20	7.78	0.20	2.57
F_2	4	13	20	33	47	57	64	59	44	21	12	4	4	373	8.13	1.05	12.91

or 1.4% less variation than was found in the DPL 15 parent. These low coefficients of variation suggested that the parents were relatively homozygous for fiber strength.

Thus in 1955, when the F_1 and F_2 generations were grown, the mean difference between the parents was 2.81 Pressley index units. This is a relatively large difference in regard to fiber strength, with no overlapping of plants in the two parents (Table I).

The F_1 population consisted of 20 plants, which ranged in Pressley index from 7.40 to 8.11, or 0.71 units. The mean Pressley index of the F_1 was 7.78 and the standard deviation was 0.08. The coefficient of variation for the F_1 mean was lower than found for either parent. This suggests that the F_1 population was not subject to as much environmental variation as plants of the parents, a condition frequently found in F_1 populations which show a strong degree of hybrid vigor. It is apparent that the F_1 resembled the low strength DPL 15 parent more closely than the Sea Island parent, a somewhat surprising relationship for a quantitative character. This relationship will be discussed in greater detail later.

The F_2 population of 373 plants showed a complete, continuous range from 5.78 to 10.65 units of Pressley index. This range included four plants in the class below the range of the weaker (DPL 15) parent and four plants in the class immediately above the range of the stronger (Sea Island) parent. In view of the large difference between the parents in fiber strength and the fact that the parents represent different species, the recovery of plants resembling each parent in an F_2 population consisting of fewer than 400 plants was surprising. These recoveries of plants phenotypically weaker than and stronger than the respective parental extremes suggests the possibility of transgressive segregation.

The F_2 population was distributed in a nearly symmetrical, unimodal manner. This distribution indicated that fiber strength, as measured by Pressley index, behaved as a quantitative character in this interspecific cross.

The mean and modal class center of the F_2 population was 8.20. There were 144 plants having a Pressley index exceeding the modal class, and 165 plants having a Pressley index below that of the mean and modal class. The coefficient of variation for the F_2 population was 12.9%, considerably higher than either parent. This high coefficient of variation for the F_2 population was due to both genetic and environmental variation.

Dominance. The mean Pressley indices for the F_1 and F_2 populations were 7.78 and 8.13 units, respectively. The arithmetic average of the parents was 8.48 units. Thus, the F_1 and F_2 populations were 0.70 and 0.35 Pressley index units, respectively, lower than the arithmetic average of the parents, indicating partial dominance of weak fiber. With absence of dominance, both the mean of the F_1 and F_2 should have been intermediate. In fact, the partial dominance shown for weak fiber was very strong in the F_1, approaching complete dominance. This marked degree of partial dominance for weak fiber is unusual for a quantitative character. Genetic studies of fiber strength in crosses between varieties of Upland cotton have shown essentially absence of dominance. The strong dominance for low strength of fiber in the F_1 of the Upland X Sea Island hybrid is one of several unusual features that were found to be characteristic of this interspecific hybrid. Although strength of fiber behaved in a quantitative manner in the interspecific hybrid, the behavior was not that of a typical quantitative character.

However, the F_2 results did not indicate the strong degree of dominance for low strength found in the F_1. In fact, the F_2 showed approximately normal distribution, with the mean occurring within the modal class and essentially the same number of plants on each side of the mode. These results are characteristic of segregation for a quantitative character with absence of dominance, although the mean of the F_2 was somewhat lower than the arithmetic average of the parents. This inconsistent behavior in F_1 and F_2 suggests that major genetic or cytological differences exist between the two parental species and that these differences have a disturbing effect on expression of strength in the hybrid offspring. Thus, results comparable to those reported in hybrids between Upland varieties cannot be expected in this material.

Nature of Gene Action. The expected arithmetic and geometric means of the F_1 were 8.48 and 8.37 respectively. The expected arithmetic and geometric means of the F_2 were 8.13 and 8.12. Since both expected arithmetic and geometric means for the F_1 were considerably in excess of the observed value (7.78), and expected arithmetic and geometric means of the F_2 were essentially identical, it was not possible to establish the nature of gene action.

Number of Genes Involved. The mean difference between the parents was 2.81 Pressley index units. Due to its quantitative nature, it was impossible to determine accurately the number of genes by which the parents differed for fiber strength. However, the following methods were employed in estimating the minimum number of genes: (1) the Castle-Wright formula, (2) the Wright formula, and (3) the frequency of recover of parental genotypes in the F_2.

(1) The Castle-Wright formula for estimation of the minimum number

of genes involved gave an estimate of 1.7, or one to two pairs of genes. This estimate was probably an underestimation of the gene number, as all assumptions of the formula did not apply. In cases where any of the following assumptions do not apply, the formula may give a value which may be smaller than the true gene number. The assumptions are: (a) all genes are equal in contribution, (b) absence of dominance, (c) gene effect is cumulative, (d) parents represent extremes for the characters.

(2) The Wright formula for estimation of minimum number of genes by which the parents differed gave a value of 1.1, indicating that the parents differed by at least one to two pairs of genes. However, the Wright formula also leads to an underestimation of gene number if the following assumptions are not met: (a) no linkage between pertinent genes, (b) one parent supplies only plus factors and the other only minus factors among those in which they differ, (c) all genes are equally important, (d) the degree of dominance for all plus factors is the same, (e) no interaction exists between pertinent non-allelic genes.

Thus, both the Castle-Wright and the Wright formulae probably did not provide accurate estimations of the minimum gene number by which the parents differed in this F_2 population. It is probable that the parents differed by a considerably larger number of genes than estimated by the formulae.

(3) Frequency of recovery of parental genotypes in the F_2 population should provide an indication as to the number of genes involved. As pointed out earlier in the F_2 population of only 373 plants a large number resembled each of the parents phenotypically (Table I). In fact, 10 of the F_2 plants were as strong as the mean of the strong fibered Sea Island parent and a larger number were as weak as the mean of DPL 15. This

suggests that F_2 plants with the genotype of each parent may have been recovered in a population of 373 plants, which would mean that only a few pairs of genes governed the difference between the parents in Pressley index. However, in view of the large parental difference and the fact that the parents represented different species, this conclusion appears to be questionable.

A more reliable indication of whether any plants genetically identical to the parents were obtained in F_2 is provided by progeny tests of these plants in F_3. Pressley index determinations on blended ten plant bulk samples from each of 80 F_3 lines and the parents are given in Table II, along with strength values of F_2 plants from which the lines were derived for comparison.

As shown in Table II, 18 of these F_2 plants produced F_3 lines within the range of the seven plots of DPL 15 and 10 of the lines had means as low as the average of DPL 15. In addition, 11 other F_3 lines which were derived from F_2 plants above DPL 15 in strength but had means similar to DPL 15 in 1956. However, because of the partial dominance for low fiber strength, the correct interpretation of these results is uncertain.

There were six F_2 plants, within the range of the Sea Island parent, which were carried into the F_3 generation as F_3 progenies. Three of these six plants gave rise to progenies as strong as the range of the Sea Island parental rows and three were as strong as the mean of Sea Island. An additional six F_3 lines from F_2 plants with lower strength proved to have means within the range of the plots of Sea Island. This suggests that several F_2 plants may have been genetically similar to Sea Island.

Despite this strong evidence that F_2 plants identical to both parents in genetic makeup were obtained in a relatively small population, it is

Table II

Pressley index values
for
DPL 15, Sea Island, F_3 lines and F_2 plants which gave rise to the F_3 lines.

Progeny Number	F_3 Value	F_2 Plant Value
DPL 15		
27	6.83	
107	6.86	
79	6.96	
93	7.20	
65	7.21	
41	7.31	
13	7.51	
$\bar{X}$	7.13	7.08
C.V.	3.53%	4.24%
Sea Island		
28	8.73	
94	9.03	
42	9.15	
66	9.19	
14	9.21	
108	9.46	
80	9.74	
$\bar{X}$	9.22	9.89
C.V.	3.46%	2.78%

Table II (cont'd.)

Progeny Number	F_3 Value	F_2 Plant Value
64	6.62	5.97
112	6.67	6.90
95	6.92	7.17
23	6.93	7.48
56	7.00	6.34
15	7.01	7.22
16	7.07	6.82
86	7.07	7.07
106	7.07	7.21
6	7.09	7.20
115	7.12	8.34
100	7.14	7.08
25	7.15	7.42
68	7.15	6.92
114	7.17	7.85
91	7.20	6.94
58	7.20	7.32
62	7.22	7.74
85	7.23	7.16
90	7.25	7.36
48	7.29	7.43
83	7.31	7.96

Table II (cont'd.)

Progeny Number	F_3 Value	F_2 Plant Value
40	7.35	7.71
32	7.35	7.35
59	7.41	8.78
33	7.44	8.23
35	7.45	7.63
61	7.47	7.68
96	7.49	7.96
98	7.52	7.17
70	7.57	8.17
97	7.62	8.77
111	7.62	8.92
72	7.63	7.55
92	7.64	7.82
22	7.72	8.09
52	7.72	7.80
102	7.72	7.31
26	7.77	7.62
39	7.77	8.18
82	7.83	8.02
75	7.84	8.48
84	7.85	7.89
45	7.86	8.35

Table II (cont'd.)

Progeny Number	F_3 Value	F_2 Plant Value
73	7.87	8.27
113	7.90	8.03
5	7.95	7.81
31	7.97	8.76
7	7.98	7.55
74	7.99	8.66
47	8.05	8.67
69	8.10	8.33
49	8.12	8.48
60	8.13	8.38
18	8.14	8.42
36	8.15	8.71
76	8.15	8.66
67	8.18	8.15
99	8.23	9.53
57	8.27	8.57
105	8.31	8.37
44	8.32	8.23
71	8.34	8.82
104	8.39	8.21
77	8.45	10.33
38	8.54	9.25

Table II (cont'd.)

Progeny Number	F_3 Value	F_2 Plant Value
50	8.62	8.84
10	8.63	7.88
54	8.67	9.15
43	8.78	8.71
46	8.82	9.01
81	8.87	8.75
2	8.96	8.70
110	9.00	9.87
88	9.01	8.86
109	9.24	9.44
53	9.25	9.14
89	9.28	9.16
34	9.39	9.69
3	9.62	10.22
$\bar{X}$	7.86	8.14
C.V.	9.52%	10.92%

difficult to accept the conclusion that the parents differed in only a few genes for fiber strength.

Estimates of the number of genes involved in the inheritance of fiber strength in intervarietal hybrids of Upland cotton have been reported by Stafford(16) and Self and Henderson(15). In these reports gene number estimates have ranged from three to five. It would be surprising to find that the two distinct species do not differ by any more genes than do some varieties of Upland cotton.

It is probable that the F_3 lines which resembled the parents phenotypically were not actual recoveries of the parent genotypes. However, the occurrence of several F_3 lines with exceptionally high strength among the 80 lines is very interesting from the viewpoint of using this hybrid in a cotton breeding program intended to combine the high fiber strength of Sea Island with desirable agronomic characters of DPL 15.

The results even suggest the possibility of transgressive segregation for Pressley index in the hybrid. Four F_2 plants were lower in strength than any plant of the DPL 15 parent in 1955 and four plants were higher than any plant of Sea Island (Table I). One of the F_2 plants with strength below the range of DPL 15 was progeny tested in F_3. The results are shown as line number 64 in Table II. It will be noted that the mean of this line was considerably below the average strength of the DPL 15 plants grown that year and was considerably below the average strength of any plot of the DPL 15 parent. Also, a second F_3 line, number 112 in the table, had a mean strength below that of any plot of DPL 15.

One F_2 plant with strength above the range of Sea Island was progeny tested in F_3 (see line number 77, Table II). However, this line had a mean of only 8.45, well below the weakest plot of Sea Island and indicating that this plant was not a transgressive segregate for higher strength than Sea Island. In fact, none of the F_3 lines appeared to have stronger fiber than Sea Island.

There is a distinct possibility that the recovery of F_3 lines lower in strength than DPL 15 was due to the occurrence of physiologically unbalanced genotypes in F_2, resulting from abnormal segregation in the interspecific hybrid. The occurrence of partially sterile plants in F_2 and F_3 is evidence that such abnormal segregates were present.

Heritability and the Effectiveness of Selection. In a breeding program, the breeder is interested in establishing varieties which represent improvement in quantitative and qualitative economic characters. Neither quantity nor quality can be sacrificed in a successful new variety. However, selection for a character on an individual plant basis in the early segregating generations may or may not be reliable, depending upon the influence of environment. Therefore the breeder needs to know the approximate degree of reliability of selection for a character, particularly in the early segregating generations where maximum genetic variability occurs. Heritability is the proportion of genetic variation in a population in relation to the total variation. The higher the heritability value, the greater is the chance of the breeder to effectively select for the character on an individual plant basis.

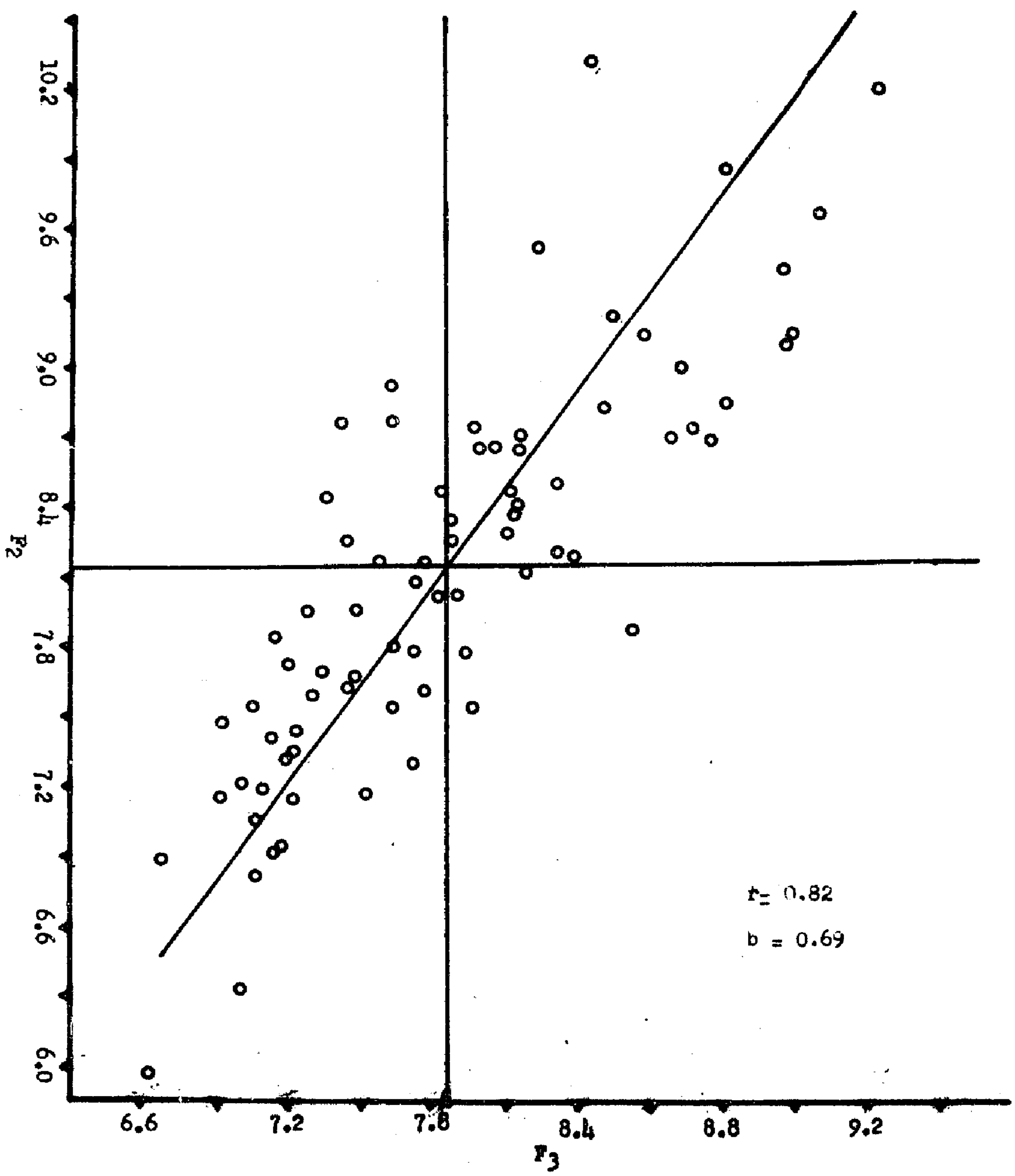
The heritability value from F_2 data for fiber strength, as measured by Pressley index, was 90.3 per cent. This suggests that 90 per cent of the variation occurring among plants in the F_2 was genetic in nature. In an intervarietal hybrid in *G. hirsutum* of Half and Half X Wilds, Stafford[16] reported a heritability value of 65%, and stated that this value was probably higher than it should have been. Thus, the heritability value from the F_2 data in the present cross was unusually high.

The probable reason for obtaining the higher values when calculating heritability in the F_2 of this interspecific hybrid was due to interaction of environment and genotype. In a wide cross, such as DPL 15 X Sea Island, there was no reason to believe that all F_2 genotypes were affected the same by environment as the average of the parents. Yet the assumption that the influence of environment on the F_2 population was no greater than on the parents is basic to the application of the formula. If this basic assumption is not met, there will be a tendency to overestimate heritability. However, due to the obvious physiological unbalance and low productivity of numerous F_2 plants, it is probable that the F_2 population was more subject to environmental variation than the parents. Under these conditions, the heritability value for the F_2 population would probably be unusually high. At the present time, there is no satisfactory method of estimating genotypic-environmental interaction in populations handled in the conventional manner as this population was handled.

As another and more effective means of estimating heritability, Pressley index determinations from a 10 plant bulk sample from each F_3 line were compared with values of F_2 plants giving rise to these F_3 lines (Figure 1 and Table II). The coefficient of correlation for F_3 bulk sample means with F_2 plant values was 0.82. This coefficient was highly significant. The regression coefficient of F_3 line means with F_2 plant values was 0.69. Thus, by this method heritability was estimated to be 69%. These heritability values indicate that approximately 70 to 80 per cent of the variation occurring in the F_2 population was genetic in nature. Both estimates gave relatively high values for a quantitative character.

The relative effectiveness of selection based on the ability of apparently superior F_2 plants to produce superior F_3 progenies is perhaps the most reliable method of estimating the degree of success the breeder

Figure 1. Scatter diagram of Pressley index for 80 F_3 bulk line means and F_2 plants giving rise to these lines.



Inheritance of Fiber Strength (0.125 Inch Strength Index)

Fiber strength, as measured with the 0.125 inch spacer, was determined for each plant of the parent, F_1, F_2, and F_3 populations. There is evidence that tensile strength of fiber measured in this manner provides more valuable information than Pressley index, in which strength is determined without space between the clamps. Table III shows the frequency distribution and calculated values for the parent, F_1 and F_2 populations. Fiber from the same prepared samples used in Pressley index determinations (presented earlier in Table I) was used for 0.125 inch strength index evaluations.

The mean strength index, using the 0.125 inch spacer between the clamps of the Pressley strength tester, for the DPL 15 parent was 3.46 pounds per milligram of fibers cut to the standard length of 0.589 inches. Fiber strength values for this parent ranged from 3.06 to 3.78. This represents a range of 0.72 units. The standard deviation and coefficient of variation of the DPL 15 parent were 0.18 and 5.2%, respectively.

The Sea Island parental population had a mean of 5.73. The range in this parent was from 5.38 to 6.14, or 0.76 units. The standard deviation of this parent was 0.19 and the coefficient of variation was 3.4%.

These parental values for the coefficient of variation parallel closely those previously reported for Pressley index. Coefficient of variation values of this low magnitude suggest that the parents were relatively homozygous for fiber strength and that the effect of environment on fiber strength among plants in these parental populations was relatively low. The mean difference between the parents was 2.27 pounds per milligram.

The F_1 population ranged from 4.33 to 4.63 units of 0.125 inch would experience in plant selection work and consequently of heritability. For the 80 F_2 plants carried into F_3, if only those high strength F_2 plants with a Pressley index of 8.70 or above had been selected, 53 per cent would have produced F_3 lines with a mean Pressley index of 8.70 or above. On the other hand, only 14% of the entire 80 F_3 lines had means of 8.70 or above since the 80 F_2 plants were chosen at random for progeny testing in F_3. This figure of 14% represents the percentage of high strength lines which would be obtained in F_3 without selection for fiber strength in F_2. The difference between 14% of high strength F_3 lines without selection and 53% obtained following selection in F_2 is an indication of how effective selection in F_2 would have been. This represents a marked increase in the percentage of superior F_3 lines and it can be concluded that selection in F_2 for high fiber strength would have been highly valuable in isolating superior F_3 lines.

Values for heritability and estimates of the effectiveness of selection indicate that it would be both feasible and desirable to practice selection for fiber strength in the early segregating generations of this species cross.

strength index, or a range of 0.30. The F_1 mean was 4.49. The standard deviation of this population was 0.08 and the coefficient of variation was only 1.8%. This appreciably lower coefficient of variation in F_1 than found for either of the parents indicates that the F_1 plants were not subject to as much environmental variation as plants of each parent.

The F_2 population of 373 plants had a mean of 4.58 and ranged from 3.36 to 6.21, or 2.85 units of 0.125 inch strength index. There were no F_2 plants in the 6.1 class, however, the plant in the 6.3 class had a value of 6.21 which just barely placed it in the higher class. Otherwise, the range of the F_2 population was continuous. The standard deviation was 0.65 and the coefficient of variation was 14.2%. With the exception of one plant, in the 6.3 class, all F_2 plants were within the range of the plants of the parents. However, several F_2 plants were as weak as the mean of DPL 15 or as strong as the mean of Sea Island.

The frequency distribution data shown in Table III show a nearly symmetrical unimodal curve in the F_2 in which the mean occurred in the modal class. The F_2 population mean approached closely the arithmetic average of the parents. These data indicate that fiber strength, on the basis of 0.125 inch strength index determinations, in this interspecific cross behaved as a typical quantitative character and showed a relative absence of dominance.

Dominance. Means of the F_1 and F_2 generations were essentially identical and agreed closely with the arithmetic average of the parents. Thus, the data from F_1 and F_2 indicated absence of dominance, a characteristic of typical quantitative traits in intervarietal hybrids.

Nature of gene action. The expected arithmetic and geometric means of the F_1 were 4.60 and 4.45 units respectively. The expected arithmetic

TABLE III

Frequency distribution of fiber strength (0.125 strength) for F_1, F_2, and parent populations of a cross between DPL 15 and Sea Island

Population	Number of plants in following strength classes																	Total	Mean	Standard Deviation	C.V. %
	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.3				
DPL 15	1	9	5	5														20	3.46	0.18	5.21
Sea Island												2	5	9	5	3		24	5.73	0.19	3.38
F_1							3	15	2									20	4.49	0.08	1.78
F_2		2	6	20	22	35	54	57	54	44	39	20	11	4	4		1	373	4.58	0.65	14.19

and geometric means of the F_2 were 4.55 and 4.54. The comparison of observed F_1 mean of 4.49 and the expected arithmetic and geometric means suggested the possibility that the gene action was geometric. However, when observed F_1 and F_2 data were both compared with expected values, it was not possible to determine the exact nature of gene action because of the small difference between the expected values in the F_2.

Number of genes involved. The mean difference between the parents was 2.27 units 0.125 inch strength index. Due to the quantitative nature of fiber strength, it was difficult to estimate accurately the number of genes by which the parents differed for fiber strength. Estimates of the number of genes involved were made in the following manner: (1) The Castle-Wright formula, (2) The Wright formula, (3) The frequency of recovery of parental phenotypes in the F_2 population. These estimates are discussed separately in the order listed.

(1) The Castle-Wright formula gave an estimate of 2.59, or 2 to 3 pairs of genes. Limitations of the Castle Wright formula were discussed previously in consideration of estimated gene number for fiber strength using Pressley index as a measure of fiber strength. This formula probably provided an underestimation of the number of genes involved.

(2) The Wright formula for estimation of minimum gene number gave an estimate of 0.46 genes, or one pair. It appeared that the assumptions of the Wright formula were not valid, i.e. the material did not meet some of these assumptions, therefore the formula gave an underestimation of gene number.

(3) Frequency of recovery of parental genotypes in F_2 is perhaps the most reliable estimate of the minimum number of genes involved. Although it was not possible to determine from the F_2 results whether any

plants genetically like the parents were obtained in the population of 373 plants, there was a strong possibility that this may have occurred. As shown in Table III, 28 F_2 plants were within the range of DPL 15, with 2 of these being as low as the mean of that parent. At the other extreme, 40 F_2 plants were within the range of Sea Island, with 6 equal to or exceeding the mean of that parent. These results suggest that the number of genes involved was relatively small.

This estimate of gene number also agreed closely to that reported by Stafford[16] in the intervarietal cross of Wilds X Half and Half, and Self and Henderson[15] in the cross between AHA 50 and Half and Half. However, it is probable that the number of genes involved in a species hybrid would exceed the number of genes involved in an intervarietal hybrid and that the actual gene number in the species hybrids studied here was greater than appeared to be true.

The F_3 lines provide additional evidence concerning the genotype of the F_2 plants, and the possible number of genes involved. There were 80 F_3 lines utilized in this study, each F_3 line consisting of a minimum of 10 plants and ranging to a maximum of 25 plants per line. The F_3 population included in these 80 F_3 lines contained a total of 1346 individual plants. The frequency distribution of plants within each line and each parent population, along with the calculated statistical values, are presented in Table IV.

Due to the lack of selfed seed on some F_2 plants, only one plant with strength as low as the mean of the DPL 15 parent was tested as a F_3 line. Line 64 had the lowest mean among the 80 tested, 3.55, and a coefficient of variation of 7.4% in contrast to a mean of 3.33 and a coefficient of variation of 5.1% for the DPL 15 parent. Although line 64 resembled

TABLE IV

Frequency distribution of 0.125 strength index of F_3 lines and parents in a cross between DPL 15 and Sea Island

Line No.	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.5	6.7	N	$\overline{X}$	sd	CV%
DPL15	3	34	79	47	4																167	3.33	.1712	5.14
64		2	4	4	4	3															17	3.55	.2619	7.38
67		1	5	4	5	4		1			1										21	3.67	.4106	11.19
69	1		2	5	4	6	2														20	3.69	.2759	7.48
5	1		2	1	1	2	4														11	3.70	.3907	10.56
48	1	1		4	1	4	2	1													14	3.72	.4150	11.16
40			2	2	4	2	2	1													13	3.78	.3087	8.17
112			2	2	3	8	1	1	1												18	3.80	.2948	7.76
114			2	4	5	5	2	1		1											20	3.81	.3270	8.58
23				6	5	6	4	1	1												23	3.82	.3309	8.66
25		1		1	3	4	3														12	3.82	.2861	7.49
52		1		3	4	2	4	2													16	3.85	.3431	8.91
90				5	3	6	2	1	1												18	3.87	.3056	7.90
115			1	2	2	1	2	1	1												10	3.87	.3558	9.19
15		1	2	1	1	2	1	5													13	3.88	.4567	11.77
56			2	1	1	7	5	1													17	3.88	.2860	7.37
85			2	1	1	2	4	2													12	3.88	.3282	8.46
106		2	2	1	2	2	5	3	1												18	3.88	.2857	7.36

TABLE IV (cont'd.)

Line No.	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.5	6.7	N	$\bar{X}$	sd	CV%
68					3	9	3	1													16	3.94	.1360	3.45
72				1	2	4	5	1													13	3.94	.2285	5.86
59				3	7	5	3	4	1	1											24	3.96	.3250	8.21
86				3	6	4	7	4	1												25	3.97	.2850	7.18
16				2	4	8	3	4		1											22	3.99	.2941	7.37
22			1	2	2	2	7	6	2												22	4.06	.3192	7.86
36				2	2	2	1	4	2												13	4.06	.3346	8.24
111					4	3	5	1		1	1										15	4.08	.3303	8.10
73					3	5	6	2	3	1											20	4.10	.2604	6.35
82					5	3	1	8	3												20	4.13	.2806	6.79
100				1	1	3	5	2	2												15	4.13	.3554	8.61
38			1		2	8	2	5	3	2											24	4.16	.3851	9.26
49			1		1	2	1	2	1	1	1										10	4.16	.4798	11.53
44					2	2	3	2	2			1									12	4.18	.3828	9.16
6				1	2	3	2	3	6	1	1										19	4.22	.3951	9.36
98					1	3	1	4	1		2										12	4.23	.3865	9.14
102					2	4	1	4	5	2											18	4.24	.3527	8.32
83				1		2	3	6	3												16	4.26	.3460	8.12
62					2	5	3	5	3	3				1							22	4.27	.3938	9.22
26					2	3	7	2		1	2	2									19	4.28	.4387	10.25

TABLE IV (cont'd.)

Line No.	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.5	6.7	N	$\bar{X}$	sd	CV%
33						3	2	3	3	2											13	4.30	.2729	6.35
60				1	2		1	4	5	4											17	4.35	.3689	8.48
32					1	3	3	1	3	3		2									16	4.36	.4401	10.09
58					1	3	3	5	3	3	1	1	1								22	4.37	.4201	9.61
84				2		1	2	1	5	3	2										16	4.38	.4382	10.00
74					4	1	2	2	2	3	1	2	1								18	4.39	.5389	12.28
18						3	1	3	1	2	2	1									13	4.44	.4121	9.28
39				1		1	5	6	2		1	1	2		1						20	4.46	.5299	11.88
45					1	2	2	3	1	1	2		1		1						14	4.46	.5623	12.61
54			1			1	1	4	5	2	1	1	1								17	4.46	.4601	10.32
69					1	1	2	4	3	4		3									18	4.46	.3983	8.58
57				1	2		2	4	4	3	2		1	1							20	4.48	.5203	11.61
35						1	1	2	2	7	1										14	4.50	.2851	6.34
81					1		6	3	4	3	2	4									23	4.52	.3994	8.84
95				1		2	2	1	4	6	3	2									21	4.53	.4381	9.67
113						2	4	1	5	2		2		2							18	4.54	.4646	10.23
3			1			2	1		1	3		3	1								12	4.55	.5836	12.83
97					1	2	1	1	3	1	2		2	1							14	4.55	.5618	12.35
31							2	2	5	3	1	2									15	4.56	.2839	6.23

TABLE IV (cont'd.)

Line No.	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.5	6.7	N	$\bar{X}$	sd	CV%
10					1	1	1		1	2	2	1	1								10	4.57	.4909	10.74
50					1		4	2	2	4	2	2	1								18	4.57	.4372	9.57
99						1		4	5	3	4	1									18	4.57	.2982	6.53
46						1	1		5	2		2									11	4.59	.3665	7.98
96						1	1	4	1	3	4	2									16	4.59	.3845	8.38
76						1	3	3	1	5	1	2						1			17	4.63	.5426	11.72
53						1	1		3	2	2	3									12	4.64	.4020	8.66
70					1			3	3	4		1	1	1							14	4.66	.3909	8.39
104							2	5	4	2	2	3	2	1							21	4.70	.4157	8.84
92							1	4	3	1	3	5									17	4.71	.3440	7.30
88							1	3		2	1	2	1	1							11	4.76	.4687	9.85
7					1		1	2	2	3	3	2	3	1							18	4.77	.4868	10.21
2						1	2	1	3	1	4	4	1	1	1						19	4.80	.4940	10.29
109							1	3		5	4	3	3								19	4.80	.3654	7.61
105				1		1		1	2	1		3			1		1				11	4.81	.7663	15.93
89									5	1	5	1		1	1						14	4.84	.3631	7.50
47							1		7	2	2	3	1	2	1						19	4.85	.4376	9.02
61								1	3	4	4	3		1	1						17	4.86	.3506	7.21
77								1	3	6	4	3	2	2	1						22	4.93	.3659	7.42

TABLE IV (cont'd.)

Line No.	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.5	6.7	N	$\bar{X}$	sd	CV%
43							1		2	3	3	1	5	1							16	4.94	.3813	7.72
75									1	3	6	5	3								18	4.96	.2189	4.41
110								1	3	3	4	4	3		2						20	4.96	.3681	7.42
71									3	3	2	5	4	1	2						20	5.03	.3191	6.34
S.I.									1	9	25	52	31	27	4	1					150	5.18	.2539	4.90
34										4	2	1	6	1	1		1			1	17	5.27	.5253	9.97
Total F_3 Pop.	3	9	33	70	120	183	176	179	166	139	94	91	47	19	13	1	2	1	0	1	1346	4.33	0.561	12.96

DPL 15 rather closely, and may have been homozygous, it is apparent that this line was not identical genetically to the DPL 15 parent.

Line 34 was the only F_3 line having a mean closely resembling the Sea Island parent. The values for this line were: mean of 5.27, standard deviation of 0.52, a coefficient of variation of 10.0% and a range from the 4.70 class to the 6.70 class. It is possible that line 34 represented the genotype of the Sea Island parent.

Thus, on the basis of frequency distribution, line means, standard deviations and coefficient of variation, there was only one F_2 parent carried as an F_3 line which represented a probable genotypic recovery of the Sea Island parent. The results are somewhat surprising but are consistent in indicating that the wide difference between the parents, which represented different species, was governed by only a few genes.

Actually two F_3 lines, 71 and 34, had essentially the same high strength as the Sea Island parent and appeared to be genetically stable. This is highly encouraging from the viewpoint of using the DPL 15 X Sea Island hybrid in a breeding program designed to combine the high fiber strength of the latter with the superior agronomic traits of the former.

Another feature of interest in the F_3 data was the occurrence of several plants with higher strength than any of the 150 plants of Sea Island, particularly in line 34. It is possible that these plants had a gene combination resulting in fiber strength exceeding that of the high strength parent and constituted transgressive segregates.

<u>Heritability and the effectiveness of selection</u>. Heritability in the F_2 population was estimated as 85%. This value is quite high, and probably somewhat higher than it should be due to the interaction of environment and genotype in the F_2 population. This value is unusually high for a quanti-

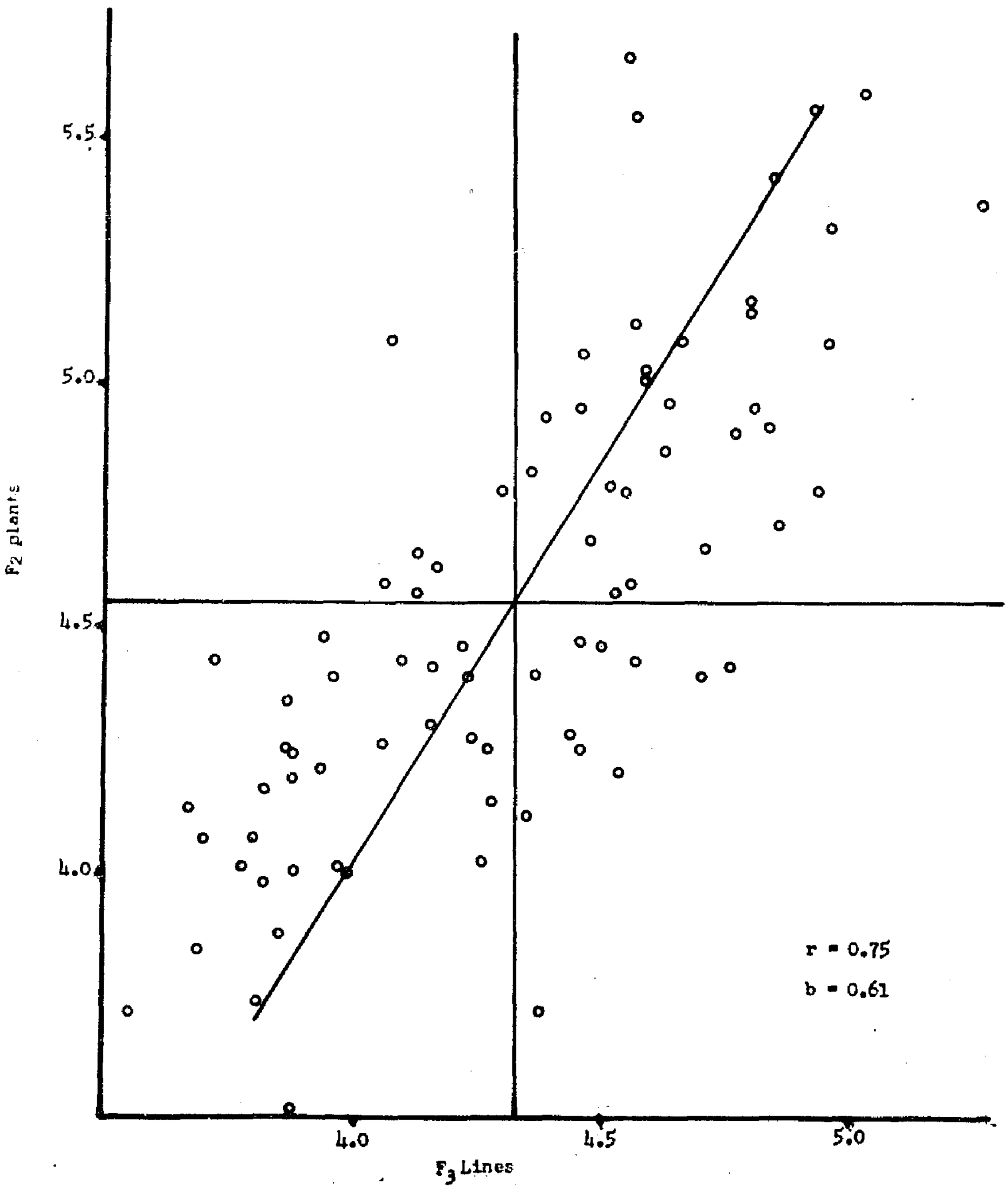
tative character and is probably due to conditions discussed earlier in heritability of Pressley index.

Additional data for heritability was provided by the F_3 population. A scatter diagram for F_2 plant values and means of F_3 lines derived from them is presented in Figure 2. The correlation coefficient of F_3 line means with F_2 plant values was 0.75. This is significant and relatively high, indicating close association between the two populations. Figure 2 shows that the regression coefficient of F_3 line means on F_2 plants was 0.61. If the regression coefficient, expressed as a percentage, is considered an estimate of heritability, the heritability estimate would be approximately 60%. This estimate of heritability is high for a typical quantitative character, indicating that most of the plant-to-plant variation in F_2 was genetically controlled and that selection in F_2 for high fiber strength would have been valuable in obtaining high strength lines.

The effectiveness of selection, on an individual plant basis, in the early segregating generations, where genetic variability is greatest, determines selection procedures followed in the breeding program. For the 80 F_2 plants carried into the F_3, if only those F_2 plants having relatively high fiber strength of 4.80 or above had been selected, 55% would have produced F_3 lines with a mean of 4.80 or above; whereas only 15% of the entire 80 lines had means of 4.80 or above. The latter figure is an indication of the percentage of F_3 lines with high strength that would have been obtained without selection in F_2. This represents a decided increase in the proportion of high strength lines through selection in F_2.

A second estimate of the effectiveness of selection was obtained by the determination of the highest strength F_2 plants carried as F_3 lines and the per cent of these lines which produced the higher F_3 line means.

Figure 2. Scatter diagram of 80 F_3 lines and the F_2 plants giving rise to the F_3 lines in respect to 0.125 inch strength index.



On this basis of comparison, 60 per cent of the superior F_2 plants carried as F_3 lines produced superior lines. Thus selection should prove to be 50 to 60% effective. These values for effectiveness of selection indicate that it would be both feasible and desirable to practice selection for fiber strength in the early segregating generations of this species cross.

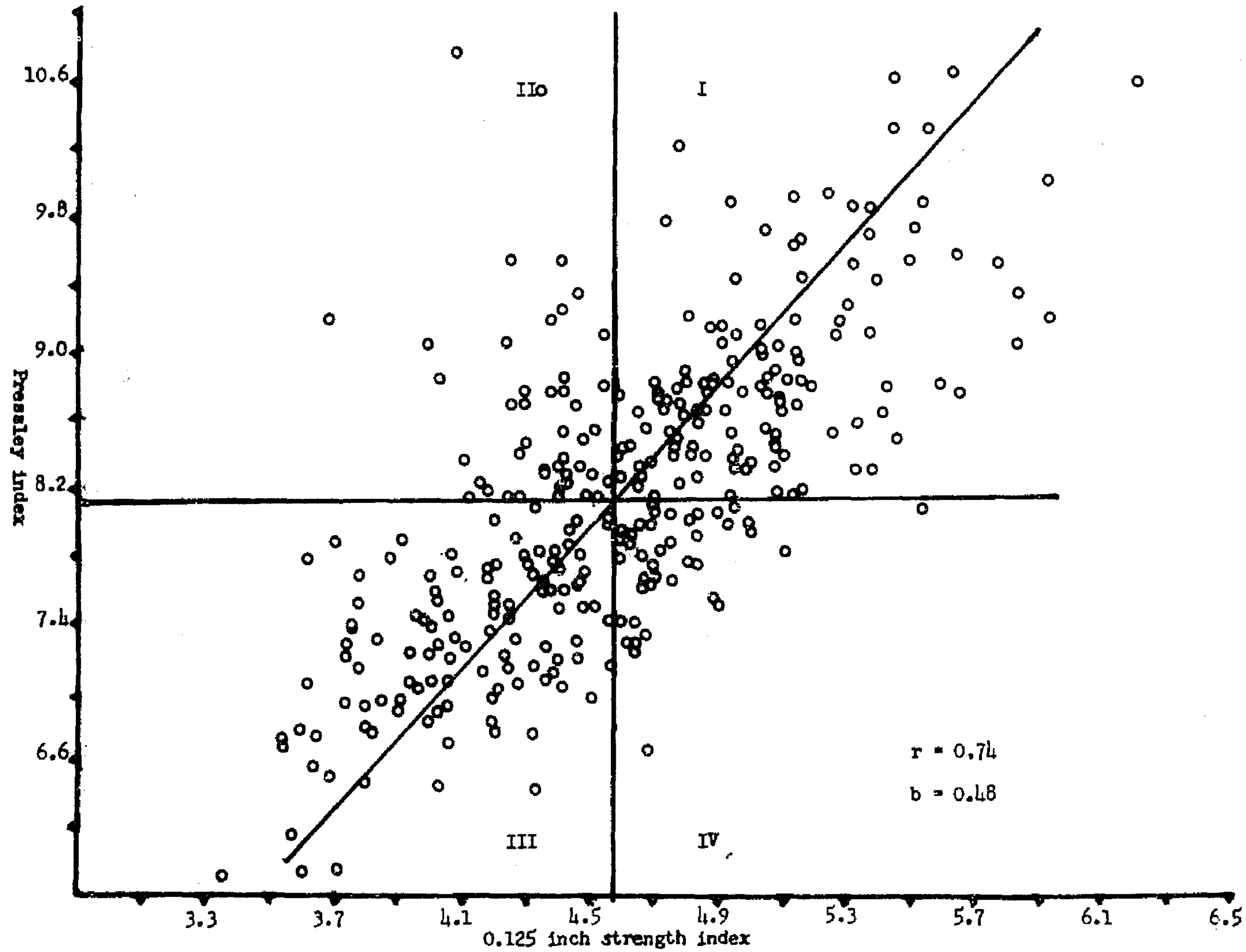
The Relationship between Pressley and 0.125 Inch Strength Indices.

The relationship between the two measures of fiber strength, Pressley index and 0.125 inch strength index, in the F_2 population of the hybrid between DPL 15 and Sea Island is shown as a scatter diagram in Figure 3.

The correlation coefficient of Pressley strength index with 0.125 strength index was 0.74. This value is significant and relatively high, indicating a close association between the two measures of fiber strength. The closeness of this association is also indicated in Figure 3. Except for a few plants which were high in Pressley index but below average in 0.125 strength index, there was good agreement between these two measures of strength. Plants which were very low in Pressley index were, with few exceptions, also below average in 0.125 inch strength index. Furthermore, with the exception of only two plants, all F_2 plants with exceptionally high Pressley index, 9.80 or above, were above average in respect to 0.125 inch strength. The two F_2 plants in Figure 3 with Pressley index of approximately 10.60 but lower than average in 0.125 inch strength were outstanding exceptions to this association.

Although the correlation coefficient between the two measures of fiber strength in the present study was lower than that reported in discussions of unpublished work at other experiment stations, it was still high and all comparisons indicated a close relationship. Although breaking strength of the fiber was much higher with the clamps at zero gauge than at 0.125 gauge, it appeared from the F_2 data that the fiber properties which determined tensile strength at the zero gauge were also the primary ones determining strength at the wider gauge. The few exceptional plants suggest that occasionally an F_2 segregate may occur which has very high

Figure 3. Scatter diagram of Pressley index with 0.125 inch strength index of a cross between DPL 15 and Sea Island.

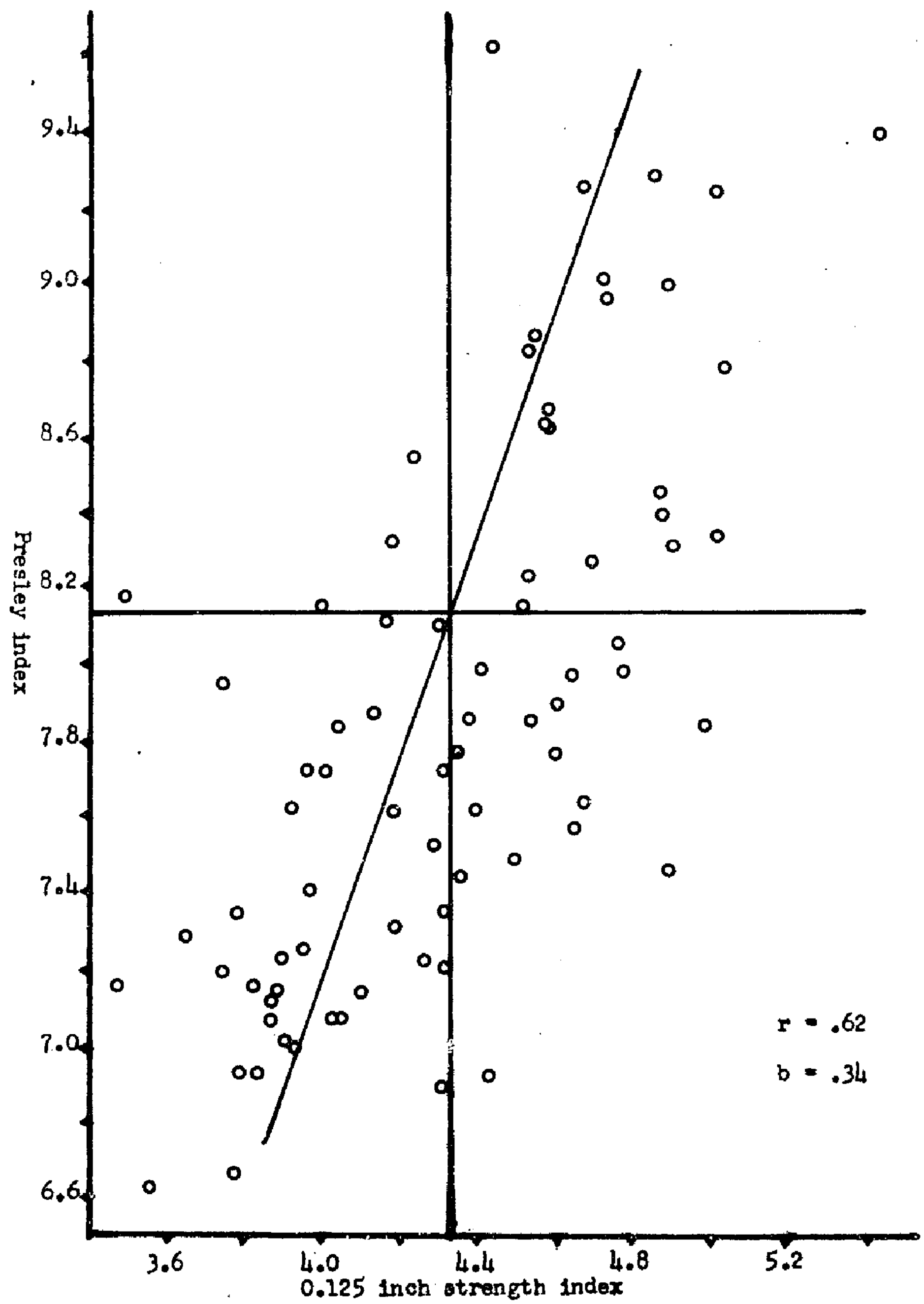


strength when measured at zero gauge but has only ordinary strength at 0.125 gauge.

Results from the F_3 population are more reliable for measuring the association between the two measures of fiber strength in respect to genetic variation affecting both since means of the F_3 lines could be used for calculating the correlation coefficient.

In the F_3 population, two correlation coefficients were calculated between Pressley index and 0.125 inch strength index. The first coefficient calculated was for the mean 0.125 inch strength index of the first ten plants of each of the 80 F_3 lines with the Pressley index of a blended bulk sample of these ten plants. This coefficient was 0.62 and statistically highly significant. The scatter diagram of Pressley index of the blended bulk sample and the 0.125 inch strength index mean of the same ten plants is shown as Figure 4. The second correlation coefficient calculated was the relationship between Pressley index and 0.125 inch strength index for 35 randomly selected lines, with both strength determinations based on the blended bulk sample. This correlation coefficient (0.66) was highly significant and of approximately the same magnitude as the first. However, the correlation coefficient between the two measures of strength for the 80 F_2 plants which were subsequently carried as F_3 lines was 0.84.

Figure 4. Scatter diagram of Pressley index of 10 plant bulk line samples and mean 0.125 inch strength index of the same 10 plants tested individually.



The calculation of two closely similar correlation coefficients from somewhat different material in the F_3 population provides strong evidence that the correlation for means of F_3 lines between the two measures of strength was about 0.65 and that the association illustrated in Figure 4 is highly reliable.

That a general association occurred between Pressley index and 0.125 strength index of the 80 F_3 lines is shown by the significant, moderately high correlation coefficient and the distribution of the lines in Figure 4. Practically all lines with low Pressley index (7.40 or below) were below average in 0.125 inch strength index and all F_3 lines with high Pressley index (8.60 and above) had higher than average 0.125 inch strength index. However, it is also apparent from Figure 4 that the agreement was not exceptionally close. For example, there were five F_3 lines with exceptionally high Pressley index values above 9.20. Yet two of these lines were only slightly above average in 0.125 inch strength index. Even more remarkable was the fact that among the 11 lines with high 0.125 inch strength index (4.80 and above), two lines were well below average in Pressley index and four others were only slightly above average and would have been considered ordinary on the basis of their mean Pressley index. In fact, only three of these 11 superior F_3 lines actually appeared to be outstanding from their Pressley index.

Thus, despite the significant correlation it is obvious that some F_3 lines were outstandingly high in mean Pressley index but only ordinary in respect to 0.125 inch strength index and that other lines had extraordinarily high strength at 0.125 gauge but were only poor to average in Pressley index. This lack of close agreement between Pressley index and 0.125 strength index provides proof that the fiber characteristics which determine high strength by the two methods of measurement are not identical and a measure of Pressley index alone would not be adequate for selecting lines with high strength at 0.125 gauge. One measure could not be used as a reliable substitute for the other.

Dr. E. H. Pressley, in conducting the Upland cotton breeding program in Arizona, found a somewhat higher relationship between 0.125 inch strength index determinations and yarn strength than between Pressley index and yarn strength. In this unpublished work, no explanation was offered for the higher correlation values obtained with 0.125 inch strength index. This higher correlation of 0.125 inch strength index with yarn strength may have been due entirely to the increase in the weight, or number of fibers in the ribbon, i.e. to a more accurate sampling of fibers. However, this is doubtful, as both measurements of fiber strength could be duplicated to a very high degree.

Wakelham and Spicer[18] have presented evidence that the structural reversals of cellulose deposition in the cotton fiber constitute a "weak link in the chain". In their studies with a variety of G. barbadense and one of G. hirsutum, they found that increases in specimen length increased the number of breaks involving reversals, and as moisture content increased, the number of breaks involving reversals increased. Any treatments which modified cellulose structure or damaged the fiber so as to reduce fiber strength decreased the number of reversal breaks. There was no significant relationship between fiber cross-sectional shapes, or maturity, and the fraction of fiber breaks at reversals. These results may offer a partial explanation for the decrease in magnitude of the correlation between Pressley index and 0.125 inch strength index.

Any physiological condition causing failure of a uniform deposition of the secondary cell wall could possibly account for changes in the relationship between Pressley index and 0.125 inch strength index because of the physical nature of the differences between the two fiber strength determinations.

The clamps holding the fiber for Pressley index strength determinations are essentially together, i.e. the bundle of fibers is broken in a very restricted area. Thus, since the area in which the fiber can break is severely restricted, Pressley index determinations would be dependent upon the relative number of "weak spots" in this area.

The fiber strength determinations with a space of 0.125 inches between the clamps provides a wider area over which each individual fiber, of the bundle being broken, can break. Thus the strength determination with the spacer, provides a measurement of fiber strength based on the weakest point in each cotton fiber which occurs in the area between the clamps.

Therefore, if the cotton fiber does contain "weak" spots, regardless of their cause, the fiber strength determinations with the 0.125 inch spacer should provide a more reliable estimate of the ability of a given cotton to produce a given yarn strength. This is due to the fact that when yarns break, the individual fibers usually break at their weakest point. Obviously, a cotton showing high Pressley index, but containing numerous weak points, could not be expected to produce a yarn having strength greater than that of the weaker points of its individual fibers. The 0.125 inch strength determinations should give a value which more closely approximates evaluation of the intrinsic yarn strength of the sample being tested.

If the cotton fiber were of uniform strength throughout its entire length, the relationship between Pressley index and 0.125 inch strength index could be expressed as a ratio. This ratio would remain constant for all cottons, as the only difference would be in the increase in length of the ribbon of fibers and the corresponding increase in weight. However, for the commercial cottons presently being grown in the United States, experience has shown that the ratio between the strength indices varies not only from variety to variety but also with environmental conditions. This ratio between the two strength indices might prove to be a means of eliminating, from the breeding block, material which showed considerable lack of uniform distribution of fiber strength of the individual fibers. Undoubtedly, distribution of cellulose is at least partially under genetic control. One would expect, other factors remaining equal, that the actual yarn strength of a cotton having a high Pressley index but a low 0.125 inch strength index, would more closely approximate the yarn strength predicted on the basis of 0.125 inch strength index than that predicted on the basis of Pressley index.

Correlation of Characters

In all breeding programs, one of the more important aspects is that of the association of characters. Breeders attempt to combine useful quantitative characters such as yield and desirable quality present in separate stocks in a single economic variety. Associations between these characters may facilitate or prove disadvantageous to the transfer of useful germ plasm into an economically desirable variety. In order to achieve the desired objective, the establishment of a superior variety, the breeder frequently employs knowledge of the association of characters in the planning of his breeding program.

Character association may be due to (1) linkage of genes governing the different characters, (2) pleiotropic effect of genes (3) physiological relationship, in cases where a change in one character may provide better conditions for expression of the other, and (4) the physical dependency of one character on the other, that is the expression of one character is dependent to a certain degree upon the physical state of another character. The magnitude of the correlation coefficient is of considerable importance to a breeding program. Generally any value less than 0.4, irrespective of significance, is not considered to be of much importance.

In the F_2 population, Pressley index and 0.125 inch strength index were correlated with fiber fineness characters and four components of yield in an effort to determine the degree of association between these characters. Correlation between fiber strength and each of the following characters in the F_2 population: seed index, lint density index, lint index, lint per cent, fiber wall thickness, perimeter, weight fineness and immaturity, or shape factor. The correlation coefficients for these associations are shown in Table V.

It will be noted from the table that neither of the two measures of fiber strength was correlated significantly with seed index, lint density index, lint index or lint per cent. Since the parents differed widely in all of these characteristics, these results indicate that no linkage occurred between genes for fiber strength and those governing these other traits and that no difficulty of this nature would be encountered in attempts to combine the high strength of Sea Island with the superior expression of these four traits from DPL 15.

There were highly significant negative correlations between Pressley index and wall thickness and 0.125 inch strength index and wall thickness. These correlations, however, were very low in magnitude (-0.17 and -0.14) and did not indicate an association which would be of any importance in a breeding program.

The association between Pressley index and perimeter and 0.125 inch strength index and perimeter were negative. However the association between Pressley index and perimeter (-0.11) was not statistically significant. In the case of 0.125 inch strength index, there was a highly significant negative (-0.15) correlation. However this value was too low to be considered of any importance in a breeding program.

The correlation between Pressley index and weight fineness and 0.125 inch strength index and weight fineness were highly significant and negative (-0.26 and -0.27). Although these values were highly significant, their magnitude was too low to be of any great importance in a breeding program.

There were no significant relationships between either Pressley index

Table V

Correlation coefficients for fiber strength
with
other characters among 308 F_2 plants of
a cross between DPL 15 and Sea Island

Variables Correlated		r
Pressley index with	seed index	-.02
	lint density index	-.09
	lint index	-.07
	lint per cent	-.06
	wall thickness	-.18**
	perimeter	-.11
	weight fineness	-.26**
	immaturity	.09
0.125 inch strength index with	seed index	.03
	lint density index	-.11
	lint index	-.06
	lint per cent	-.09
	wall thickness	-.14*
	perimeter	-.15**
	weight fineness	-.27**
	immaturity	.07

and immaturity (shape factor) or 0.125 inch strength and immaturity.

Genetic correlation coefficients between 0.125 inch strength index and wall thickness, perimeter, and weight fineness were essentially the same as the simple correlation coefficients, i.e. the values were of approximately the same magnitude, as is shown in Table VI. The significance of these values is not known, as no satisfactory error term has yet been offered.

The correlation between the two measures of fiber strength and the three components of fiber fineness, i.e. weight fineness, perimeter, and wall thickness, probably can be explained as a physical relationship which will be discussed in more detail later.

In the F_3 population, correlation coefficients were calculated between the line mean for 0.125 inch strength index and the line mean for the same characters as in the F_2 population, with the exception of immaturity (shape factor). These relationships are shown in Table VII.

In the F_3, as in the F_2, there was no significant relationship between fiber strength and seed index, lint density index, lint index or lint per cent.

Fiber strength (0.125 inch strength index) and wall thickness was found to be negative and highly significant (-0.37). The increase in probability (as compared to the F_2) that this value did not represent chance variation, may have been due to differences in the growing season or seasonal effect. However, there is no evidence to prove that this was the case. A correlation value of this magnitude is of some importance in a breeding program, whether the relationship be due to genetic linkage or to a physical relationship.

The correlation coefficient between fiber strength and perimeter in

Table VI

Comparison of genetic correlation coefficients and simple correlation coefficients for fiber strength with certain fineness components for 308 F_2 plants of a cross between DPL 15 and Sea Island

Variables Correlated		Genetic r	r
0.125 inch strength index with	wall thickness	-.14*	-.14
	perimeter	-.15**	-.15
	weight fineness	-.27	-.32

Table VII

Correlation coefficients for fiber strength with other characters among 80 F_3 lines of a cross between DPL 15 and Sea Island

Variables Correlated		r
0.125 inch strength index with	seed index	.12
	lint density index	-.21
	lint index	-.09
	lint per cent	-.21
	wall thickness	-.37**
	perimeter	-.41**
	weight fineness	-.49**

the F_3 lines was negative (-0.41) and highly significant. This relationship is of sufficient magnitude to warrant the attention of the plant breeder. The possible nature of the relationship will be discussed later.

There was a highly significant negative correlation (-0.49) between 0.125 inch strength index and weight fineness. Although the significance of the relationship remained the same in the F_2 and F_3, the increase in magnitude of the F_3 correlation coefficient is of interest. The magnitude of the relationship in the F_3 is of considerable interest and importance to the plant breeder.

The correlation coefficients between fiber strength and the fiber fineness characters of wall thickness, perimeter and weight fineness may have been due to genetic linkage. However, experience has shown that these relationships may be of a physical rather than a genetic nature.

If these correlations result from a physical relationship between fiber strength and fiber fineness components, then correlations of these characters in each of the parental populations should be of the same magnitude, if the assumption is made that the parents are homozygous and that any variation in the characters is due to environmental conditions. There were 166 and 150 plants respectively of the DPL 15 and Sea Island parents. Populations of this size should be adequate to estimate the degree of relationship of the characters. The correlation coefficients are shown in Table VIII. All correlation coefficients except for fiber strength with perimeter (in the Sea Island parent only) were negative and highly significant. The magnitude of these values very closely approximated those found in the F_3. This would be expected if the relationships were physical rather than genetic in nature.

Therefore, on the basis of these data, it appears that the relation-

Table VIII

Correlation coefficients for fiber strength with certain fiber fineness characters for the 166 and 150 plants of the DPL 15 and Sea Island parents.

Variables Correlated		r DPL15	r Sea Island
0.125 inch strength index with	wall thickness	-.35**	-.45**
	perimeter	-.37**	-.01
	weight fineness	-.41**	-.42**

SUMMARY AND CONCLUSIONS

A study of the inheritance of fiber strength was made in the parents, F_1, F_2 and F_3 generations of a cross between DPL 15 and Sea Island (SA 339) varieties of cotton. The parental varieties were of the two different cultivated species of New World cotton, namely Gossypium hirsutum and Gossypium barbadense. The study was conducted utilizing fiber strength measurements of Pressley index and 0.125 inch strength index. Plants of the F_1 and F_2 generations were tested individually utilizing both strength measurements, whereas the plants of the F_3 population were tested individually utilizing only the 0.125 inch strength index.

The results led to the following conclusions pertaining to the inheritance of fiber strength and its association with other characters.

(1) There was little genetic variation in plants of either parent. The variation found in parental populations was probably due to environment.

(2) The variation found among F_1 plants was less, percentage wise, than in either parent. This was considered an indication that the F_1 was less subject to environmental variation than the parents.

(3) Fiber strength was concluded to be quantitatively inherited.

(4) The F_1 and F_2 showed partial dominance of weak fiber where fiber strength was measured by Pressley index, but showed absence of dominance when fiber strength was evaluated by 0.125 inch strength index.

(5) No conclusions could be reached from the data as to the nature of gene action.

(6) The parental means differed by 2.81 units Pressley index and 2.27 units 0.125 strength index. Data indicated that the parents differed by

only a few pairs of genes for this wide parental difference. There appeared to be more genes segregating for 0.125 strength index than for Pressley index.

Although methods of estimation of the number of genes by which the parents differed were not highly refined, it was concluded that fiber strength was conditioned by a relatively small number of genes and that a breeder could expect a reasonable frequency of recovery of parental phenotypes in a comparatively small segregating population.

(7) Probable transgressive segregation for fiber strength, as measured by Pressley index, occurred in the F_2 population. One possible transgressive segregate was carried as an F_3 progeny. The progeny of this plant was 0.21 units lower than the lowest line value of the DPL 15 parent.

There was no evidence of transgressive segregation in the F_2 population when fiber strength was measured by 0.125 inch strength index. In the F_3 population, there were at least 2 plants which represented transgressive segregates. These two plants were 0.38 and 0.80 units 0.125 inch strength index higher than the highest plant of the Sea Island parent.

(8) Plants within F_3 lines showed continuous variation in only 36 of the 80, or 45 per cent lines.

One F_3 line probably represented a recovery of the Sea Island genotype, whereas there were no probable recoveries of the genotype of the DPL 15 parent.

(9) The date indicated that fiber strength, as measured by 0.125 inch strength index could be more complex in its inheritance than Pressley index.

(10) The reliability of estimates of heritability varied. F_3 results were found to be the most reliable in the estimation of heritability.

On the basis of F_3 data, it was concluded that a breeder could expect approximately 50 to 60 per cent of the high strength F_2 plants to produce high strength F_3 lines.

From these data, it was concluded that the most advisable procedure for the breeder to follow would be one in which rigid selection should be practiced in a relatively large segregating population. This would be necessary in order to insure selection of an adequate number of superior plants.

(11) Correlation data for the F_2 population showed a highly significant, but low, negative relationship between Pressley index and wall thickness and Pressley index and weight fineness.

(12) The 0.125 inch strength index fiber strength determinations showed a significant inverse relationship to wall thickness and perimeter, and a highly significant, but low, negative correlation with weight fineness.

(13) All of these relationships were interpreted as being of a physical nature, and not due to linkage.

(14) There was no relationship between fiber strength and seed index, lint density index, lint index, lint per cent and immaturity, or shape factor.

(15) In the F_3 population, 0.125 inch strength index was not associated with seed index, lint density index, lint index and lint per cent. Highly significant negative correlation coefficients were found between 0.125 inch strength index and wall thickness, perimeter, and weight fineness. These coefficients were of sufficient magnitude to be of importance in a breeding program. However, when the same characters were correlated with fiber strength of the DPL 15 parental population, grown along with

the F_3, virtually the same coefficients were obtained. The relationship between 0.125 inch strength index and weight fineness was essentially of the same magnitude among plants of the Sea Island parent, however there was no relationship between strength and perimeter in this parental population.

(16) These data indicate that the relationship between strength and the fiber fineness characters was of a physical nature and was not due to any genetic linkage of these characters.

ships between 0.125 inch strength index and wall thickness, perimeter, and weight fineness in the segregating populations were due to a physical relationship rather than to a genetic relationship.

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AUTOBIOGRAPHY

Smith Worley, Jr. was born June 14, 1924 in Columbia, South Carolina.

He received his primary and secondary education in the public schools of Aiken county, graduating from high school in June, 1942. He entered Clemson Agricultural and Mechanical College in September, 1942. After completion of one semester, he withdrew from college to farm.

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